National Aeronautics and
Space Administration
**Headquarters**
Washington, DC 20546-0001

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NASA

JUN 7 1995

Reply to Attn of: OI

Mr. William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, NW
Washington, DC 20554

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

Re: Ex Parte Presentation
<u>CC Docket No. 92-297</u>

Dear Mr. Caton:

Enclosed is a report by the National Aeronautics and Space Administration detailing a preliminary analysis of the Bellcore report, "Interference Analyses for Co-Frequency Sharing of the 28 GHz Band by the Local Multipoint Distribution Service (LMDS) and the Fixed Satellite Service (FSS)." Our report provides an initial assessment of the Bellcore findings, discusses several areas of concern and identifies those areas that are still under investigation by NASA. We will provide additional information to the FCC assessing the work still in progress in the near future.

We respectfully request that the enclosed information be associated with the above referenced processing because it addresses issues relevant to the proceeding.

Sincerely,

Charles T. Force
Associate Administrator for
Space Communications

Enclosure

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cc:
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NASA Comments on the Bellcore Study

## Introduction

The Bellcore study entitled "Interference Analyses for Co-Frequency Sharing of the 28 GHz Band by the Local Multipoint Distribution Service (LMDS) and the Fixed Satellite Service (FSS)" purports to show that LMDS and FSS co-frequency sharing is feasible in the 28 GHz band. This is opposite to the conclusion drawn by the NRMC in its report to the FCC.

In this study, Bellcore contends that all interested parties should evaluate interference from a statistical viewpoint, rather than a view of guaranteed interference-free service. Secondly, they propose the acceptance of certain changes to the LMDS and FSS parameters that would reduce LMDS susceptibility to FSS interference. Thirdly, and probably the most significant, they recommend changing the acceptable interference threshold from the NRMC working value of 26 dB, to the range of 8-13 dB. Given these parameter changes they then present simulation results that indicate LMDS service availabilities of 99.9% and better. Fourthly, they propose a Spectrum Protocol, whereby the LMDS and FSS services operate in a pseudo-band segmentation mode, by which the LMDS services can achieve even higher availabilities.

NASA is in the process of carefully reviewing the results of this study. Working with the same assumptions as stated by Bellcore, NASA simulations show partial agreement with the Bellcore results. However, NASA would like to bring to the Commission's attention certain areas where there are differences and concerns about the assumptions and analysis that lead us to believe that this new approach is not without serious consequence to both the LMDS and FSS services.

Specifically,

- The spatial averaging, recommended by Bellcore, obscures the fact that LMDS services will frequently, if not continuously, be degraded in some areas.
- The Bellcore study essentially ignored a serious degradation of subscriber-to-hub links by FSS terminals.
- Re-specification of the LMDS parameters to partially mitigate FSS interference, as described in the Bellcore study, can aggravate the LMDS interference into FSS uplinks.
- Acceptability of interference thresholds of as low as 8 dB, as suggested by the Bellcore study, is not consistent with data filed with the NRMC report.
- The Spectrum Protocol would offer unusable spectrum to FSS service and degrade FSS service.
- Clustering of service areas is more likely than suggested by Bellcore, and it has a more

significant degradation when considering the narrow band FSS interferers.

- The Bellcore analysis addressed point solutions for specific currently filed systems (Teledesic and Spaceway) but did not consider future FSS deployment of multiple systems (particularly multiple GEO FSS systems at 2° spacing).

As a result of these concerns, NASA believes that the FCC should refrain from acting on the Bellcore conclusions. NASA is continuing to evaluate the Bellcore proposed approach and plans to provide the results of additional detailed evaluations at a later date.

## 1. Spatial Averaging Obscures Fact That Services Will Frequently, if Not Continuously, be Degraded in Some Areas

Though the Bellcore study introduction and conclusions cited availabilities of 99.9% or better, the study also indicated that clustering of FSS terminals in urban areas could result in significantly less availabilities (about 98% or less - Fig. 3-4 and 3-5). In examining the clustering results, Bellcore argued that one needed to look at availability on a *system basis*. And in the event of clustering, other LMDS cells would necessarily be nearly empty and exhibit very high availability. Averaging the results would then naturally produce a high availability overall.

All this obscures the fact that for the clustered cells, some users would always have degraded service.

## 2. The Bellcore Study Essentially Ignored a Serious Degradation of Subscriber-to-Hub Links by FSS Terminals

An LMDS system which provides data services to its subscribers can be expected to have equal bandwidth requirements in both the hub-to-subscriber and subscriber-to-hub directions. The Bellcore study discusses interference to the LMDS subscriber extensively, but interference to the LMDS hub is treated only very generally on less than one page. Interference to the hub is a particular problem because of the omni-directional antenna used by the hub. The FSS earth station will always be in the mainbeam of the hub because it is within the hub's service area.

FSS earth stations operating close to the hub and on the same frequency could cause interference to that hub, depending on the separation distance between the earth station and the hub. Like the case of interference to the LMDS subscriber, there is a required separation distance between the interferer and victim that would ensure that the hub's interference criterion is met. As calculated in the Bellcore study (Appendix A), the required separation between a transmitting earth station and a receiving LMDS hub ranges up to 2.8 km (see Table 2-1). For a 5 km radius LMDS cell, this represents 31% of the cell area. The only solution to this interference problem offered in the report is to have the FSS earth station not transmit on the same frequency on which the proximate LMDS hub is receiving. This "solution" would prohibit the FSS earth stations from using 50% of the available bandwidth over 31% of the cell area.

**Table 2-1** - Required Separation Distances for Controlling Interference into LMDS Hubs
(Extracted from Tables A-2 thru A-5 of Bellcore study)

| | Required Separation, Km | Percent of 5 Km Cell |
|---|---|---|
| CellularVision Hub | | |
| TST (16 kbps) | 2.8 | 31.4 |
| TGT (OC-24) | .1 | < 0.1 |
| Spaceway | 2.7 | 29.2 |
| TI 52 Mbps QPSK Hub | | |
| TST (16 kbps) | .2 | 0.2 |
| TGT (OC-24) | .2 | 0.2 |
| Spaceway | 1.8 | 13.0 |

## 3. Re-specification of the LMDS Hardware to Partially Mitigate FSS Interference, as Described in the Bellcore Study, Can Aggravate the LMDS Interference into FSS Uplinks.

Section 1.2 of the Bellcore study describes several LMDS system parameter changes proposed by Bellcore as a means of reducing the interference susceptibility of the LMDS systems to FSS interference. These included doubling the number of transmitters at each CellularVision hub location and simultaneously increasing the transmitter power of each from 100 W to 120 W. The effect is to increase interference into FSS satellites by 3.8 dB. For the Texas Instrument LMDS system, Bellcore recommends operation continuously at full power. This has the effect of boosting clear sky interference into FSS satellites by 12 dB. While it is true these proposed changes have a positive effect on the interference susceptibility of both the CellularVision and TI systems, they would have the opposite effect on FSS susceptibility to LMDS service. Quantification of the FSS degradation is currently under study by NASA, the results of which are not yet available.

## 4. Acceptability of Interference Thresholds of as Low as 8 dB, as Suggested by the Bellcore Study, Is Not Consistent With Data Filed With the NRMC Report

Bellcore also proposes that the allowable carrier-to-noise plus interference C/(N+I) level for the CellularVision FM video system could be reduced under both clear sky and rain faded conditions to between 8 dB and 13 dB. The result of this relaxation of performance criteria is an apparent improvement in the LMDS availability to its subscribers. Bellcore includes Table 1-2 in their report, reproduced in Table 4-1 below, which is reported to show the estimated video signal-to-noise and resultant picture quality as a function of received C/(N+I).

**Table 4-1.** Estimated video signal-to-noise ratio and resultant picture quality in the worst channel for the Cellular Vision LMDS system as a function of received carrier-to-noise plus interference ratio (Table 1-2 of Bellcore study).

| C/(N+I) | Video SNR | Picture Quality |
|---|---|---|
| 26 dB | 55 dB | Excellent |
| 18 dB | 47 dB | Fine to Excellent |
| 13 dB | 42 dB | Fine |
| 8 dB | 37 dB | Passable to Fine |

The data provided in Table 4-1 identifies a picture quality rating of "Fine" for C/(N+I) = 13 dB, and Passable to Fine for C/(N+I) = 8 dB. The data that is reported to support these numbers was provided by mm-Tech. These quality assessments, however, do not agree with the data provided by mm-Tech during the Negotiated Rulemaking Committee as contained in document NRMC/93 and subsequently included in Section III of the Committee's Report. A five grade quality scale was used in the measurements conducted by mm-Tech and reported in NRMC/93; Excellent, Fair, Passable, Marginal and Inferior in descending order of quality. Tables were provided in NRMC/93 which indicate the subjective rating assigned for various C/I ratios at differing frequency offsets for three different data rate digital interferers on an FM video signal. Measurements were taken at two C/N ratios (31 dB and 16 dB) to examine the effects under clear sky and faded conditions. The table below presents a subset of the mm-Tech data which appears on pages 16-21 of the Report of the LMDS/FSS 28 GHz Band Negotiated Rulemaking Committee.

**Table 4-2:** Subjective ratings from mm-Tech data as reported in NRMC/93 for C/N = 31 dB

| Interferer Data Rate | 64 Kbps | | | 1.544 Mbps | | | 27.5 Mbps | | |
|---|---|---|---|---|---|---|---|---|---|
| Frequency Offset (MHZ) | -5 | 0 | +5 | -5 | 0 | +5 | -4 | 0 | +4 |
| C/I = +14 dB | P | M | P | P | M | P | P | P | P |
| +12 dB | M | I | P | M | M | P | P | P | P |
| +10 dB | M | I | M | M | M | M | P | M | M |
| +8 dB | M | I | I | M | I | I | M | M | M |

where: P = Passable
M = Marginal
I = Inferior

**Table 4-3:** Subjective ratings from mm-Tech data as reported in NRMC/93 for C/N = 16 dB

| Interferer Data Rate | 64 Kbps | | | 1.544 Mbps | | | 27.5 Mbps | | |
|---|---|---|---|---|---|---|---|---|---|
| Frequency Offset (MHZ) | -5 | 0 | +5 | -5 | 0 | +5 | -4 | 0 | +4 |
| C/I = +14 dB | P | M | P | P | M | P | P | P | P |
| +12 dB | M | I | P | M | M | P | P | M | P |
| +10 dB | M | I | M | M | I | M | P | M | P |
| +8 dB | M | I | M | M | I | M | M | M | M |

Table 4-2 is representative of an interference limited environment under clear sky conditions while Table 4-3 is representative of an interference and noise limited environment in the presence of rain fading. These data from mm-Tech clearly do not support the findings presented in Table 4-1. The subjective results in tables 4-2 and 4-3 show that viewer judgements ranged from Inferior to Passable for C/I between 12 and 14 dB, not "Fine" as indicated by Table 4-1. At C/I of 8 dB, viewer judgements ranged from Inferior to Marginal and not "Passable to Fine" as shown in Table 4-1.

NASA therefore strongly questions the feasibility of basing availability percentages on performance criteria below C/(N+I) of 13 dB as proposed by Bellcore and used in their assessment of sharing feasibility. It would seem improbable that LMDS proponents would willingly accept "Inferior" to "Marginal" viewer judgements as the basis of their performance criteria. It would seem even more improbable that LMDS subscribers would accept and pay for such performance.

The mm-Tech data also shows that the subjective effect of offsetting the center frequencies of the digital interferer and the FM video signal remains essentially constant throughout the passband of the video signal and only improves when the interfering signal is offset far enough in frequency such that the digital signal is outside the passband of the video signal. In the case of the CellularVision FM video system, this occurs at approximately ± 9 MHZ offset from the frequency at which the center frequencies are coincident, due to the 18 MHZ peak-to-peak deviation of the CellularVision FM video signal. Therefore, within the passband of the FM video signal, frequency offset has virtually no effect on improving the signal quality as claimed in the Bellcore report.

## 5. The Proposed Spectrum Protocol Would Offer Unusable Spectrum to FSS Service And Degrade FSS Service

As an additional method of enhancing LMDS availability, Bellcore proposes that LMDS providers make certain portions of spectrum available for use by the FSS providers. These include the guard bands between the LMDS TV channels (about 2 MHZ each) and certain assigned TV channels (about 18 MHZ each). These assignments could vary from LMDS cell to LMDS cell and the FSS providers would be required to access and use the channels in an order determined by the LMDS provider. By this means, reportably all the spectrum would be available to the FSS provider as long as this spectrum set-aside is used first, and in the order prescribed by the LMDS provider.

Consider, for example, a Teledesic FSS service co-sharing with a LMDS provider. The FSS provider cells are much larger than the LMDS cells. A Teledesic FSS cell would encompass about 64 LMDS cells. Each LMDS cell would set aside one TV channel for FSS use. Since the Teledesic cell bandwidth is limited to 400 MHZ, a maximum of 20 distinct TV channels could be made available for the FSS service. When assigning FSS channels, the FSS provider must make the assignments according to terminal location and in the TV channel assigned by the LMDS provider for that location. As a consequence, the FSS provider has complete access to the entire spectrum, but at the loss of some flexibility in channel assignments for any one LMDS coverage area. This process can be repeated for other Teledesic cells, but for a different portion of the spectrum (to maintain isolation between Teledesic cells). Though the example illustrated use of the TV channels, the guard bands would be used in a similar manner.

Though this proposal would benefit the LMDS service, it would not support the claims made for the FSS service for the following reasons:

5.1. The offer of the guard bands for FSS service is probably irrelevant.

In down conversion for individual channel processing, it is very likely that the FSS provider satellites will make use of a block down-conversion and multiple channel processing that requires channels to be within a contiguous band. NASA has been sponsoring related system studies and hardware developments of such techniques which enable single devices which process hundreds of digital channels simultaneously. It is expected that the Cyberstar, Spaceway, and Teledesic satellites will make use of such technology. The proposed offer of LMDS guard bands would not be compatible with such technology. Each of the bands would be separated by at least 18 MHZ of unavailable spectrum, violating the contiguous spectrum requirement. Therefore, NASA views the guard bands as non-applicable and irrelevant to enhancing LMDS availability.

In addition, one LMDS proponent plans to use these guard bands for interactive services. Assigning the same to the FSS satellite service would introduce FSS interference into the LMDS hubs which would disable the interactive service for a significant portion of the LMDS cell.

5.2. Bellcore omitted the analysis of FSS service degradation resulting from the proposed Spectrum Protocol

Though the proposal states that FSS providers would have complete spectrum access, the proposed Spectrum Protocol, nevertheless, degrades FSS service availability.

Consider the Teledesic 16 Kbps service as an example. The Erlang B formula[1] would indicate that with 1440 independent 16 Kbps circuits available over a Teledesic cell, up to 1359 Erlangs of traffic could be supported with 99.9% availability[a] (the loss due to call blocking). Now consider this same scenario overlaying 64 LMDS cells, assuming uniform distribution of terminals, circuits, and traffic. Then we would have about 23 circuits per cell supporting about 21.2 Erlangs of traffic. It is recognized that 23 circuits require only 6.33 MHZ, significantly less than the 20 MHZ per TV channel set aside by the proposed Spectrum Protocol. However, if we assume the full 20 MHZ available in each LMDS cell, the total of all 64 cells exceed the satellite spectrum of 400 MHZ per satellite cell. Conceptually one could dynamically assign more or less spectrum to any given LMDS cell, but one could not do this independently of traffic in other cells. The cell-cell dependence is inherent and unavoidable. And with the uniform assumption, we must restrict each cell to 22-23 circuits.

Applying the same Erlang B formula to an individual cell would indicate an availability of only 86.6%, considerable degradation from the independent case.

In addition, the guard bands would not be useful (as described in 5.1) and this would naturally lead to lower availabilities than stated.

It is misleading to say the FSS providers would have complete spectrum access in each cell while at the same time requiring access to occur in a certain order. FSS circuit availability would inherently be degraded.

## 6. Clustering of Service Areas is More Likely Than Suggested by Bellcore, and It Has a More Significant Degradation When Considering the Narrow band Interferers.

An Addenda to the Negotiated Rulemaking Committee report[2] indicates there will be about 6000 LMDS cells nationwide. Averaging this over the approximately 250 Statistical Metropolitan Areas, there would then be about 24 LMDS cells per SMSA. Bellcore chose a 64 cell case as typical. Clearly there will be more concentration of LMDS coverage, on average, than Bellcore allowed for. An extreme example might be Las Vegas, where clearly only a few cells would be needed. The FSS terminal density ought to follow the same concentration trends, as one would expect the FSS service demand to follow population concentrations also. Hence clustering is

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[a] For a large number of circuits the Erlang B formula can be approximated by (for p <.05):

$$p \doteq \frac{\left[\frac{E}{N} e^{\left(1-\frac{E}{N}\right)}\right]^N}{\sqrt{2\pi N}}$$

likely to be the rule, not the exception.

The availability results for clustering presented in the Bellcore report are for Teledesic Standard Terminal (TST) FSS uplinks at the T1 rate interfering with CellularVision and Texas Instrument subscriber LMDS receivers. Clustering effects on availabilities were not presented for the case of SPACEWAY interferers nor for the TST FSS uplinks at the 16 Kbps rate. The SPACEWAY case omission was based on the claim that degradation would be less than Teledesic since the density of simultaneously active terminals is lower in the SPACEWAY system and because the 29.0-30.0 Ghz uplink allocation requested by SPACEWAY for use over North America only partially overlaps the 27.5-29.5 Ghz band. NASA has evaluated the effect of the TST 16 Kbps uplinks (see Appendix for details) and the results are shown in Table 6-1.

Simulations were performed for five different FSS terminal concentrations. The NASA availability result for no clustering (99.70%) agrees very closely with the Bellcore non-clustered result of 99.65%. With clustering of the terminals over smaller areas it can be seen that the availability begins to drop significantly. The availability drops to 93.8% when all active terminals are concentrated in 2 LMDS cells. The Bellcore T1 results show similar trends and approximately the same level of availability, though the Bellcore T1 results did not account for adjacent cell interference and the NASA TST-16 kbps simulations do.

Table 6-1 - Effect of Clustering of FSS TST Terminals on LMDS Availability

| CellularVision Subscriber LMDS Availability for 1440 Randomly Located Simultaneously Active 16 kbps Teledesic Standard Terminals and 13 dB C/(N+I) Performance Requirement | |
|---|---|
| Clustering Type | Availability ( assuming C/(N+I) is calculated on power basis) |
| No clustering (1440 active FSS terminals randomly located over a 53 km by 53 km Teledesic "satellite cell") | 99.70% |
| 16-cell clustering (1440 active FSS terminals randomly located over 16 LMDS cells) | 99.30% |
| 8-cell clustering (1440 active FSS terminals randomly located over 8 LMDS cells) | 98.48% |
| 4-cell clustering (1440 active FSS terminals randomly located over 4 LMDS cells) | 96.64% |
| 2-cell clustering (1440 active FSS terminals randomly located over 2 LMDS cells) | 93.83% |

In the determination of the effects of interference, the NRMC report included two approaches. The conservative (worst-case) approach was to evaluate interference by making use of the peak power density in the interference spectrum. The optimistic (best-case) approach was to evaluate interference by simply summing the total in-band interference power. The Bellcore study repeatedly described their results as "worst-case" and made reference to the use of the power density approach. NASA simulations made use of both approaches (for comparison purposes). The NASA "best-case" results nearly match the Bellcore "worst-case" results.

Table 6-2 shows LMDS availabilities as determined by Bellcore and compares them with similar NASA determinations. Table 6-3 shows the required separation distances as calculated by Bellcore and compares them with NASA determinations. Note that near agreement occurs for the NASA "best-case".

Table 6-2 - Comparison of Availability Determinations

| Interferer Type | LMDS Availability | |
|---|---|---|
| | Bellcore "Worst-Case" | NASA "Best-Case" |
| TST 16 kbps | 99.65 | 99.7 |

Table 6-3 - Required Separation Distance between a 16 Kbps TST and LMDS Receiver

| LMDS Receiver | LMDS Antenna Direction | Required Separation Distance, Km | |
|---|---|---|---|
| | | Bellcore "Worst-Case" | NASA "Best-Case" |
| Cellular Vision Subscriber | Main Lobe | 4.7 | 4.7 |
| | 5° | 0.6 | .59 |
| | 45° | 0.3 | .30 |
| | Back | 0.015 | .015 |

In Table 3-2 of the Bellcore study, it is indicated that the availability could be actually greater by up to 50% because the study had analyzed the "worst-case". The above suggests the results were actually for the "best-case" and there would thus be no room for improvement.

## 7. The Bellcore Analysis Addressed Point Solutions for Specific Currently Filed FSS Systems (Teledesic and Spaceway) But Did Not Consider Future FSS Deployments

Bellcore performed their assessments assuming only one FSS provider as interferer. To date there are three FCC filings for FSS service at Ka-band. There will likely be more filings to come. Considering the orbital arc where all of the contiguous US would be visible at an elevation of 30°

or better (to avoid severe rain fading), there would be about 6 possible satellite positions over the arc of 97 - 110° west longitude. In addition, if one were to also allow for systems that are tailored for East coast/West coast coverage (high population densities), an additional arc of 57-97° west longitude would make possible about 20 more systems. It would then seem there could be at least 3 and possibly 13 times as many interferers as was assumed in the Bellcore analysis.

## Conclusion

NASA is in the process of evaluation of the report by Bellcore examining frequency co-sharing possibilities between LMDS and FSS services. Bellcore contends sharing is feasible under the following conditions:

1. All interested parties evaluate interference from a statistical viewpoint, rather than a view of guaranteeing interference-free service.
2. Accept certain changes to LMDS parameters that would reduce LMDS susceptibility to FSS interference.
3. Reduce the interference threshold from the NRMC working value of 26 dB, to the range of 8-13 dB.

In NASA's view, the statistical approach obscures the serious effects of interference on specific LMDS suscribers and would ultimately lead to many complaints against the FSS services. Also, the availabilities determined by Bellcore study appear to be "best-case" values, not "worst-case" as described. While the changes to LMDS and FSS parameters improve availability for the LMDS service, no analysis was provided on the impact of the changes to LMDS interference into the FSS service. Though the proposed Spectrum Protocol would enhance LMDS availability, it would diminish FSS service availability.

In light of these concerns and issues, NASA believes there is insufficient demonstration to prove feasibility of co-frequency sharing between the LMDS and FSS services.

## Appendix
## NASA Simulation Procedures and Results

In an effort to verify the Bellcore availability results, NASA has begun performing computer simulations for the various interference scenarios given in the report. To date simulations have been performed for the case of 16 kbps TST uplink interference into CellularVision LMDS subscribers. Simulations for T1 rate TST interference are ongoing. Also, simulations involving interference from different types of FSS terminals within a single LMDS cell accessing multiple GEO satellites at 2° spacing along the geostationary arc are being planned. Interference from multiple GEO FSS satellite systems was not analyzed by Bellcore. Results given below apply only to the TST 16 kbps interference case.

As indicated by Bellcore, up to 1440 16 kbps TST FDM uplinks spanning a total of 400 MHz (28.6-29.0 Ghz) can be simultaneously active within a 53 km by 53 km Teledesic "satellite cell". Alternatively, each satellite cell can support 15 simultaneous T1-rate users or combinations of rates from 16 kbps to T1. A single 16 kbps channel has a burst bit rate of 225 kbps (512 bit packet/2.276 msec dwell time) and occupies 275 kHz of uplink bandwidth including guardbands. Bellcore calculates an availability of 99.65% for a randomly located Cellularvision subscriber and a threshold C/(N+I) of 13 dB (Figure 3-8). Bellcore did not investigate the effect of terminal clustering for 16 kbps TST interference.

NASA simulation results to estimate availability for the narrow band interference scenario are shown in the table below. Discussions were held with Bellcore in order to verify their simulation procedure and the parameters used in the analysis. Accordingly, the availabilities shown in the table assume the modified CellularVision LMDS link budget parameters indicated in Table 1-1 of the Bellcore report and use of the improved sidelobe LMDS subscriber antenna pattern. Operation under clear sky conditions is also assumed. Simulations were performed for five different FSS terminal concentrations. The NASA availability result for no clustering (99.70%) agrees very closely with the Bellcore result of 99.65%. This availability result assumes the C/(N+I) ratio is computed on a power basis by computing "I" as the sum of the single-entry interfering powers from all interfering terminals.[b] With clustering of the terminals over smaller

[b]It should be noted that this leads to a "best case" availability as defined in Section 4.3 of the NRMC Working Group 1 report ("Methods of Interference Calculations for FSS Earth Stations Accessing NGSO Satellites Interfering into LMDS Receivers"). While the Bellcore report indicates in Section 3.6 that narrow band interference was assessed on a worst case power density basis, recent discussions with Bellcore to seek clarification on this issue have identified that the power summation approach was also used for the Bellcore narrow band interference calculations.

areas, as Bellcore had examined with the 15 simultaneous T1 users, it can be seen that the availability begins to drop significantly. The availability drops to 93.8% when all active terminals are concentrated in 2 LMDS cells.

| CellularVision Subscriber LMDS Availability for 1440 Randomly Located Simultaneously Active 16 kbps Teledesic Standard Terminals and 13 dB C/(N+I) Performance Requirement | |
|---|---|
| Clustering Type | Availability ( assuming C/(N+I) is calculated on power basis) |
| No clustering (1440 active FSS terminals randomly located over a 53 km by 53 km Teledesic "satellite cell") | 99.70% |
| 16-cell clustering (1440 active FSS terminals randomly located over 16 LMDS cells) | 99.30% |
| 8-cell clustering (1440 active FSS terminals randomly located over 8 LMDS cells) | 98.48% |
| 4-cell clustering (1440 active FSS terminals randomly located over 4 LMDS cells) | 96.64% |
| 2-cell clustering (1440 active FSS terminals randomly located over 2 LMDS cells) | 93.83% |

The algorithm used in estimating the LMDS availability consisted of performing the following steps in a looping fashion:

1) Randomly locate the 1440 active FSS terminals throughout the 53.3 km x 53.3 km satellite cell (or throughout M LMDS cells for M-cell clustering)

2) Since the 1440 FDM channels occupy approximately 400 MHz of bandwidth and the bandwidth of a single LMDS video channel is approximately 20 MHz (including guardbands), the 1440 narrow band channels are spread over approximately 20 LMDS video channels (400 MHz/20 MHz). The occupied portion (18 MHz) of each 20 MHz LMDS video channel, in turn, encompasses about 65 narrow band FSS channels (18 MHz/0.275 MHz). Therefore, 65 of the randomly located FSS terminals are randomly assigned to LMDS video channel #1, 65 to LMDS video channel #2, and so on, all the way up to video channel #20. Since there are 20 video channels and a subset of 65 FSS terminals assigned to each video channel, interference is included from a total of 1300 FSS terminals (65 x 20) scattered throughout the satellite cell. The signals from the remaining 140 FSS terminals are assumed to fall within the guardbands between the LMDS video channels.

3) Randomly locate an LMDS subscriber within his LMDS cell and compute the desired carrier power © which is received from the LMDS hub.

4) Compute the aggregate interference power into each of the LMDS subscriber's 20 video channels from the subsets of 65 FSS interfering terminals assigned to each video channel. For example, the aggregate interference power (I) into channel #1 is found by summing the single-entry interference powers from each of the 65 FSS terminals assigned to channel #1 in step (2) taking into account their relative distances and orientations from the LMDS subscriber location.

5) Knowing the received carrier power per video channel © from step (3), the specified thermal noise power per video channel (N = -125.4 dBW), and the aggregate interference power per video channel (I) from step (4), compute the C/(N+I) ratios for each of the 20 video channels.

6) Select the worst (lowest) C/(N+I) ratio among the 20 video channels and compare it against the threshold value (e.g. 13 dB). If it is below the threshold, assign an outcome of "0"(fail). If it meets or exceeds the threshold, assign an outcome of "1"(success).

7) Go back to step (1) and repeat K times. (In our simulations, K was set to 10000.)

8) Estimate the availability (i.e. the probability that the C/(N+I) in the worst channel for a randomly located LMDS subscriber is greater than or equal to the threshold) by counting up the number of "successes" over the K trials.

References:


1. Kleinrock, Leonard: Queueing Systems Volume I: Theory, John Wiley & Sons, 1975, p. 106.

2. "CelluarVision Services", WG1/37, WG2/35, 8/12/94, Enclosure to Letter From Law Offices of Michael R. Gardner, P.C., Counsel for Suite 12